Advancement of High Power Laser Diodes for Pumping 2-micron Solid State Lasers

Farzin Amzajerdian, Byron Meadows, Michael J. Kavaya, and Upendra Singh
NASA Langley Research Center

Nathaniel Baker
Lockheed Martin Engineering and Sciences Company

Vikas Sudesh
Science and Technology Corporation

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Langley Research Center (LaRC)

MOTIVATION

Laser Diode is a critical component of lidar transmitter required for pumping the laser crystals.

Laser Diode has been identified as a major risk area in deployment of Lidar instruments in space.

Laser Diodes Establish Instrument Lifetime

BACKGROUND

Laser Diode is one of the major tasks under NASA's Risk Reduction Program

Joint LaRC/GSFC Effort:

- LaRC responsible for 792 nm wavelength Laser Diodes used for pumping 2-micron lasers
- GSFC responsible for 808 nm wavelength Laser Diodes used for pumping 1-micron lasers

Addresses Major Laser Diode Issues:

- Limited reliability and lifetime
- Lack of statistical and analytical bases for performance and lifetime prediction
- Limited commercial availability

Advancement of High Power Laser Diodes for Pumping 2-micron Solid State Lasers

Langley Research Center (LaRC)

PLAN AND OBJECTIVES

- Develop a state-of-the-art characterization facility capable of:
  - Measuring Performance and Characteristic Parameters
  - Lifetime Testing
  - Environmental Testing
- Advance 792 nm Laser Diode Array Technology
  - Packaging
  - Brightness and Pumping Efficiency
  - Fabrication Process
- Advance LD analytical models for predicting lifetime and allowing for an end-to-end lidar system design trade analyses.
- Establish a lifetime database to allow for formulating future lidar missions and performing meaningful cost and risk assessment analyses.

2-micron Solid State Coherent Lidar Transmitter

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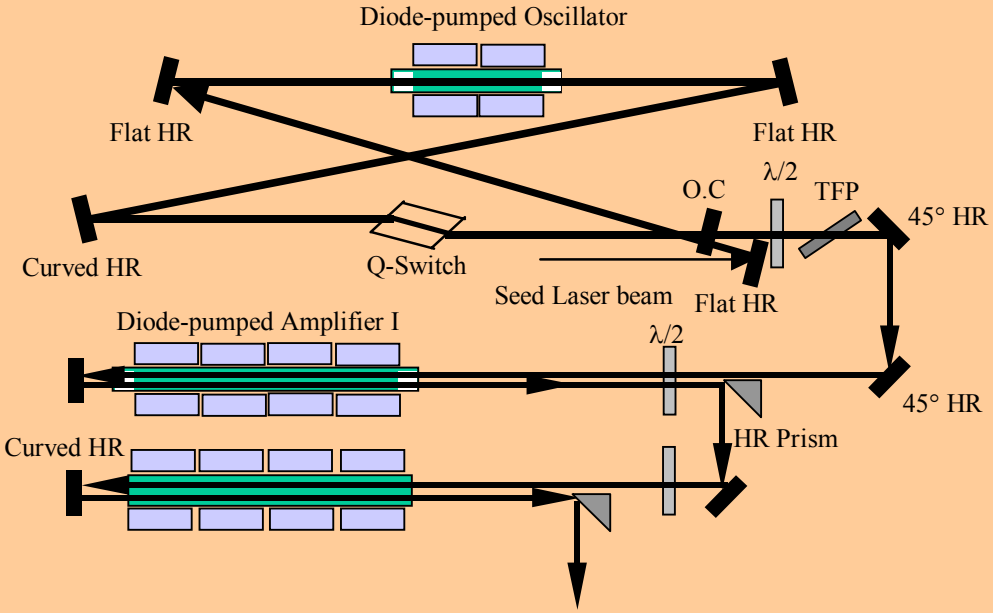
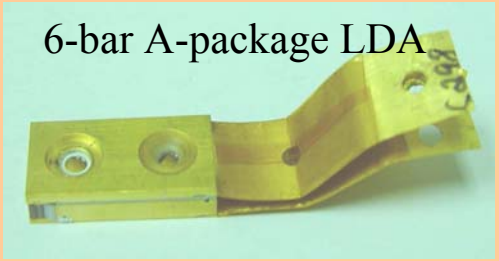
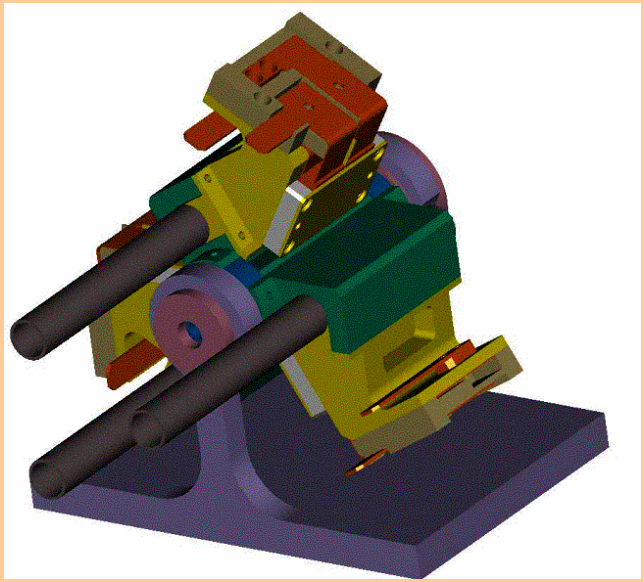
Joule-class Transmitter Laser being developed at NASA/LaRC







Fully Conductively-cooled Laser Head

Courtesy of Dr. Jirong Yu

Goal/Requirements

Parameter	Goal	Current State
Central Wavelength (nm)	792 +/- 1	792 +/- 3
Spectral Width (nm FWHM)	3	5
Peak Power Per Bar (W)	150	100
Pulse Width (msec)	1.5	1.0
Duty Cycle	3%	1%
Number of Bars	10	6
Bar Spacing (mm)	0.4	0.4
Electrical to Optical Efficiency	55%	45%
Wavelength Drift (nm/Bshots)	+/- 1	Unknown
Package	Conductively-cooled	Conductively-cooled
Lifetime (number of shots)	3×10^9	$<< 3 \times 10^9$

High Power Laser Diode Array Pump

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792nm versus 808nm

792 nm Diode Lasers for Pumping 2μm Solid State Lasers

- No Space Heritage
- Accelerated test currently not possible
- Screening and performance predication currently not possible
- Very limited commercial availability
- Pulse width: > 1ms

808 nm Diode Lasers for Pumping 1μm Solid State Lasers

- Space Heritage
- Accelerated test may be possible
  - Higher Repetition Rate
  - Elevated Temperature
- Screening and performance predication currently not possible
- Limited commercial availability
- Pulse width: ~ 200 μs

Thermal Cycling is one of the leading causes of Quasi-CW LDA degradation

Longer pulsewidth required by 2μm lasers substantially accelerates LDA degradation

Thermal Effects of Quasi-CW 792 nm Laser Diode Array

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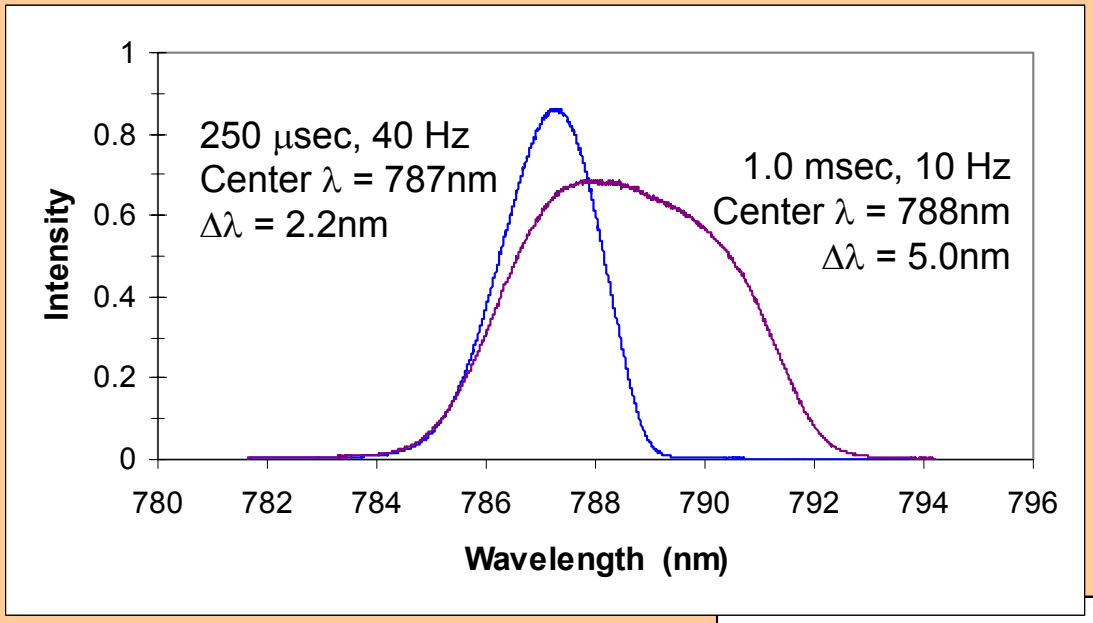
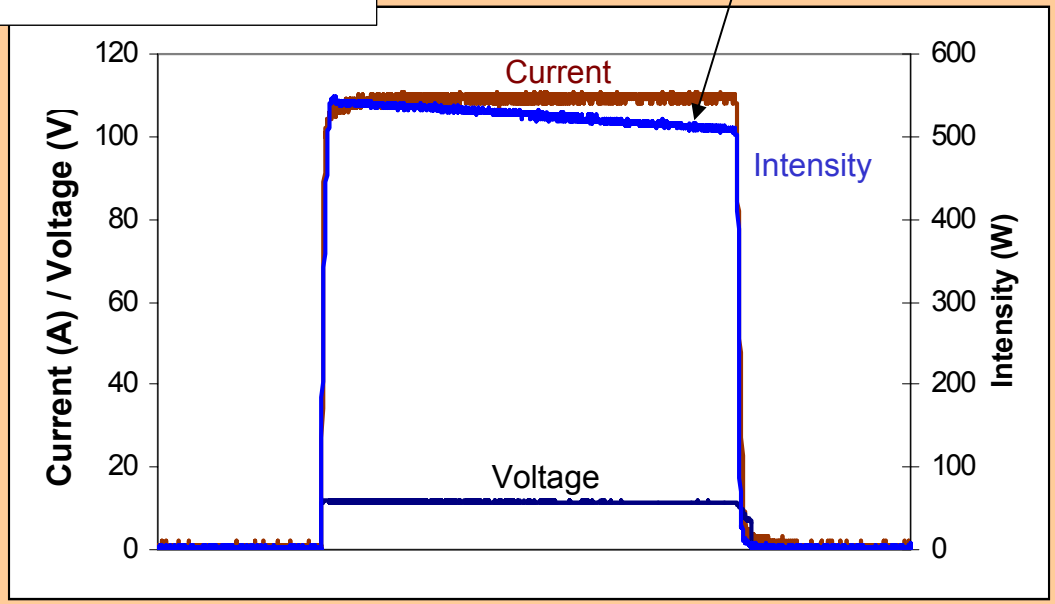


Intensity drops over 1.0 msec pulse duration due to temperature rise in diode active region



Current 110 A
Op Temp 15°C

Accelerated Lifetime Test

Lifetime $\tau = A\, I^{m}\, e^{(Ea/kT)}$

τ = Lifetime at $T^{o}K$

E_a = Activation Energy

I = Operating Current

m = Current Acceleration Constant

A = Constant

$$\tau\,(T_{op}) / \tau(T_{test}) = \exp[(E_a/k)\{(1/T_{op})-(1/T_{test})\}]$$

Laser Diode Characterization/Lifetime Test Facility

Langley Research Center (LaRC)

Capable of measuring all major characteristic parameters and performing lifetime testing.

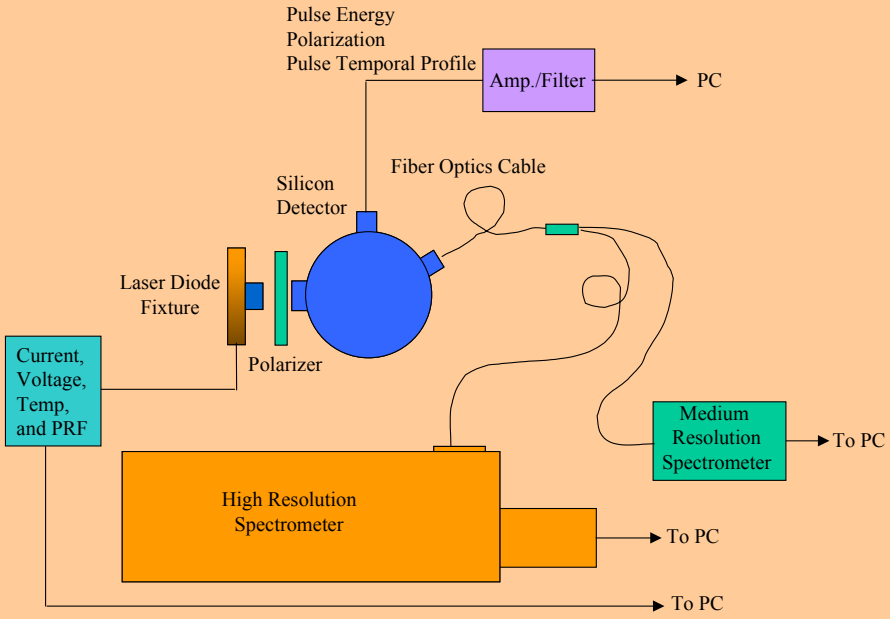
LDCF Objectives:

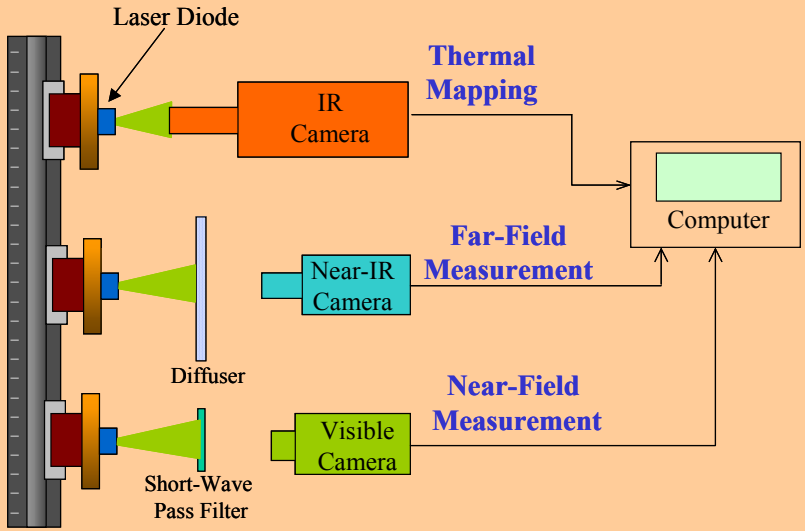
- **Improve understanding of Laser Diode Arrays**
- **Establish an independent lifetime and performance data base**
- **Investigate development of analytical models for predicting lifetime and performance, and enabling end-to-end instrument trade analyses of E, PRF, τ_p, lifetime, …**
- **Support development of advanced Laser Diode Arrays**
- **Provide experimental and analytical results to Laser Diode manufacturers in order to improve fabrication process for higher reliability and consistency**
- **Develop qualification test procedures for space-based lidar instruments**

Laser Diode Characterization/Lifetime Test Facility

Langley Research Center (LaRC)

Characterization Station





Measurements

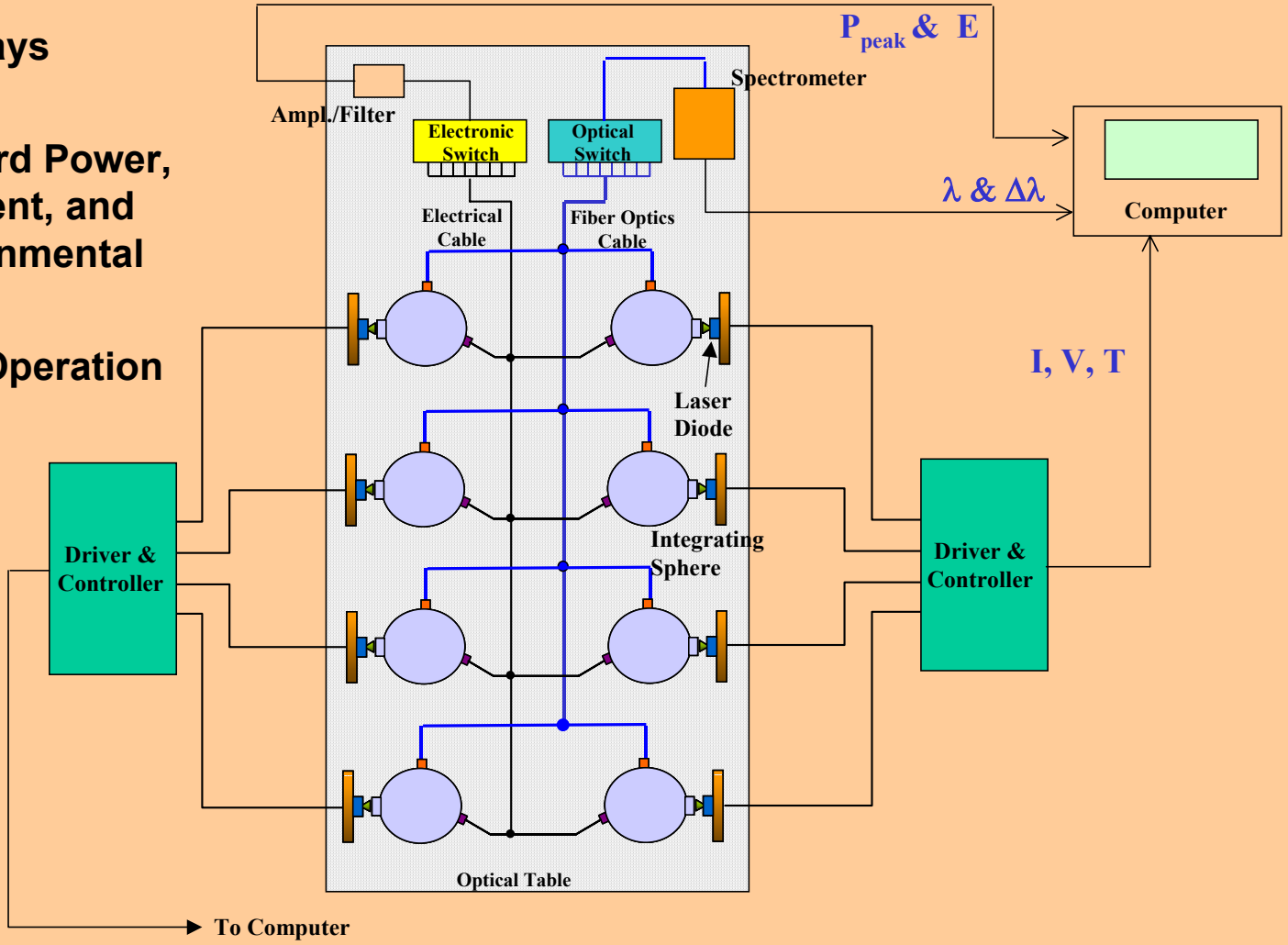
- Power and Efficiency vs. Current
- Spectral Profile
- Near Field Imaging of LD Emitters
- Polarization
- Wavelength vs. Temperature and Current
- Pulse Temporal Profile
- Spatial Profile and Beam Divergence
- Thermal Profile and Heat Removal Efficiency

Laser Diode Characterization/Lifetime Test Facility

Langley Research Center (LaRC)

Lifetime Test Station

- Measure 8 LD Arrays Simultaneously
- Measure and record Power, Wavelength, Current, and all relevant environmental parameters
- Fully Automated Operation

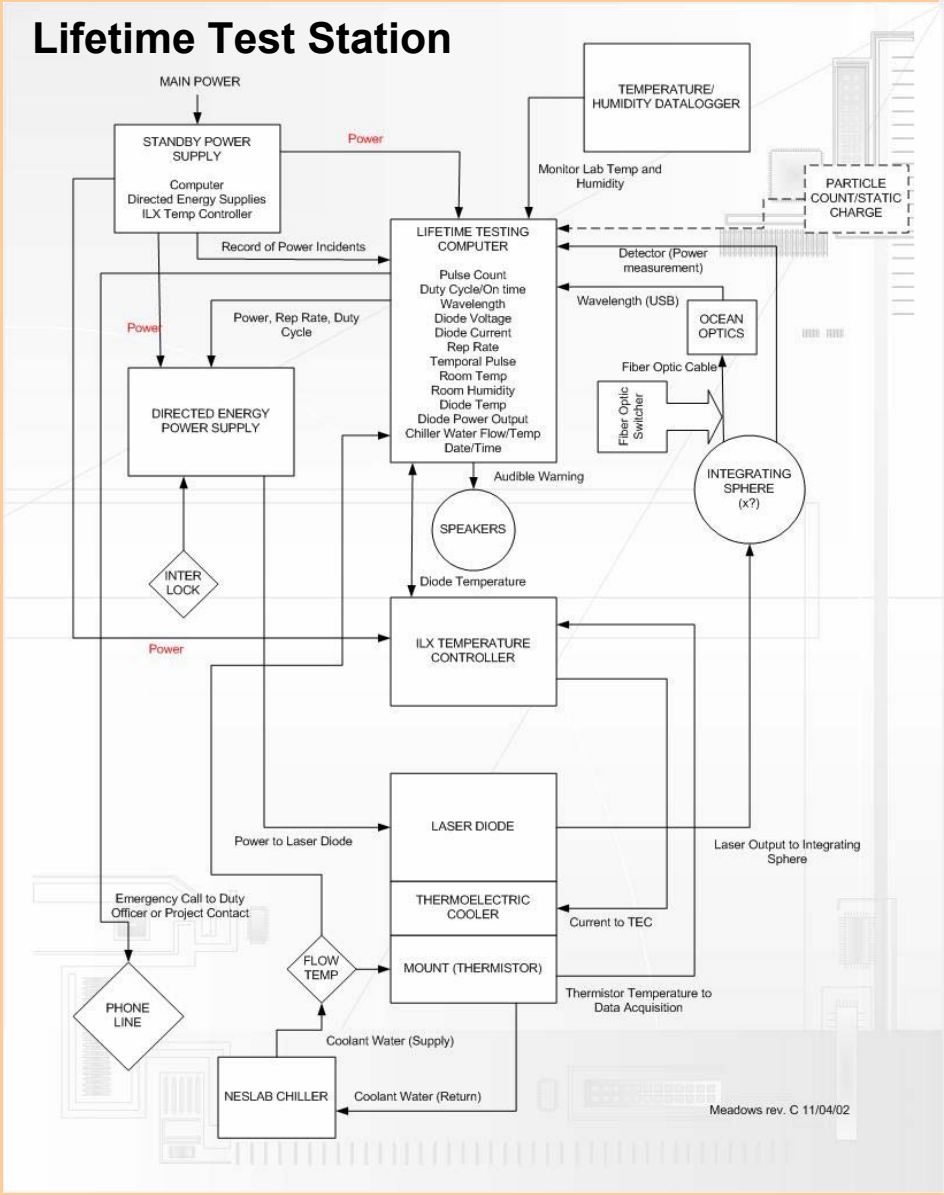


Laser Diode Characterization/Lifetime Test Facility

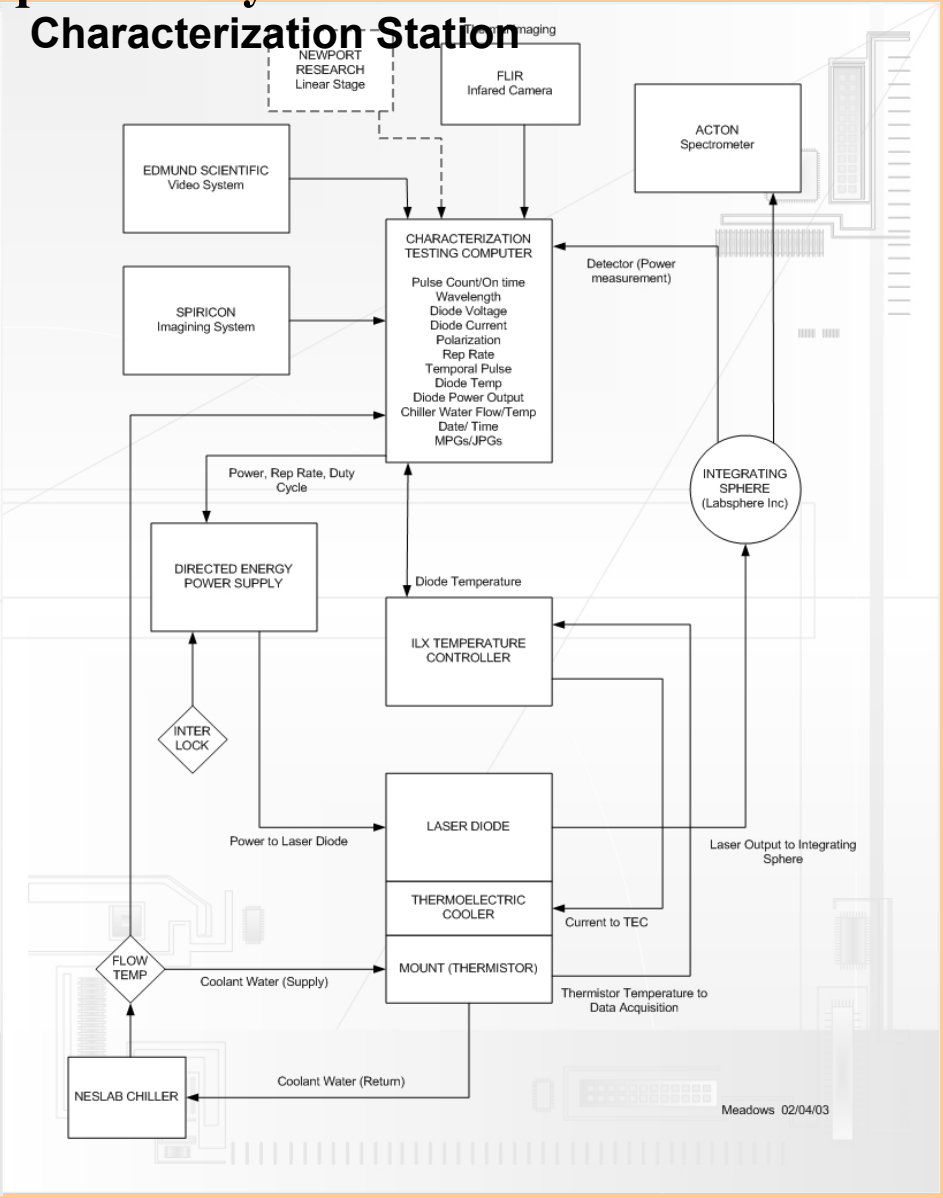
Langley Research Center (LaRC)

Control and Data Acquisition System

Lifetime Test Station



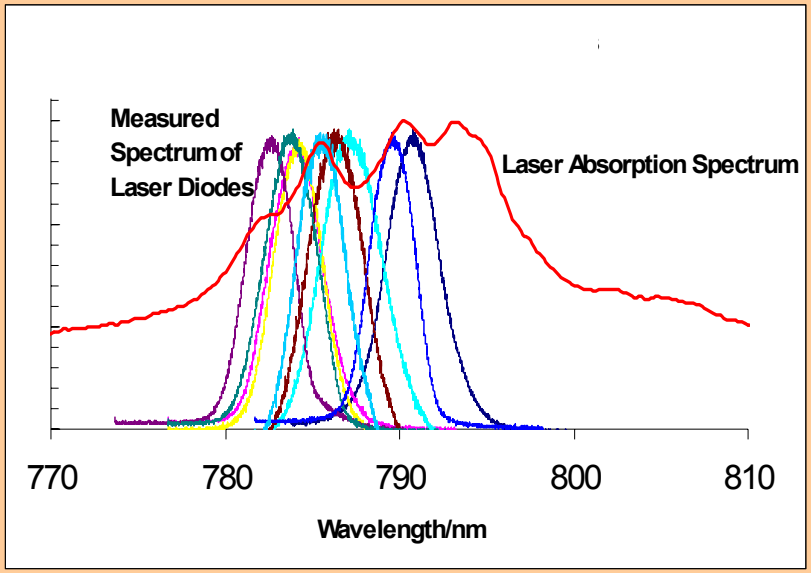
Characterization Station



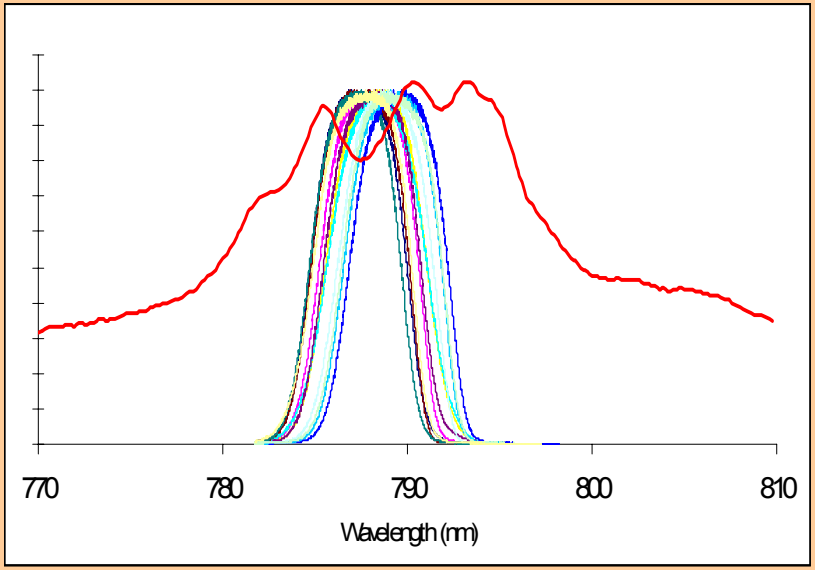
792 nm Laser Diode Array Characterization

Langley Research Center (LaRC)

Water-Cooled Laser Diode Arrays
6 bars, 360 W, C-Package



Conductively-Cooled Laser Diode Arrays
6 bars, 600 W, A-Package

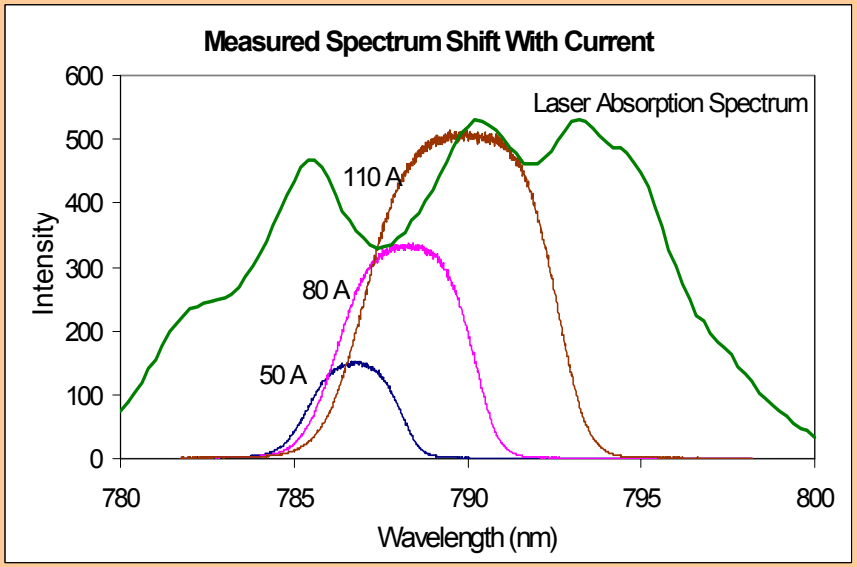


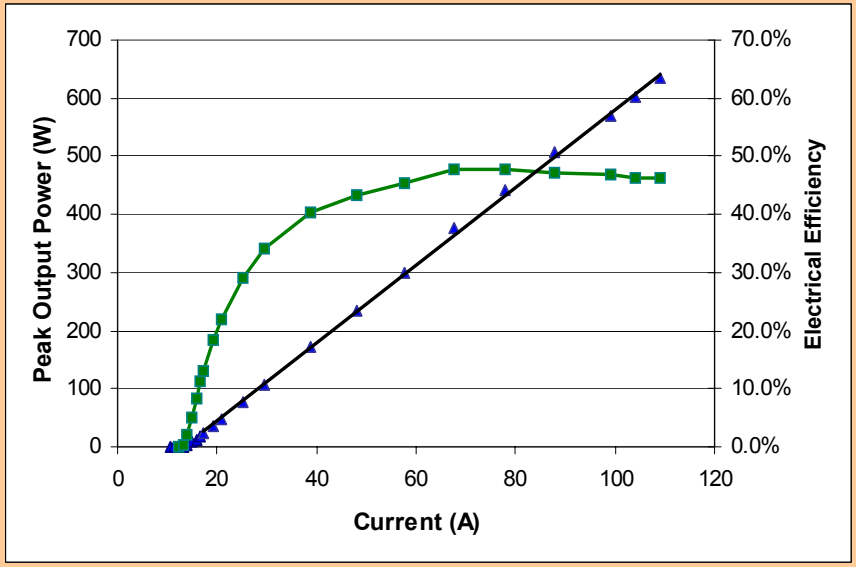
Pulsewidth	1.0 msec
Rep Rate	10 Hz
Op Temp	15°C

792 nm Laser Diode Array Characterization

Langley Research Center (LaRC)

Conductively-Cooled Laser Diode Arrays
6 bars, 600 W, A-Package



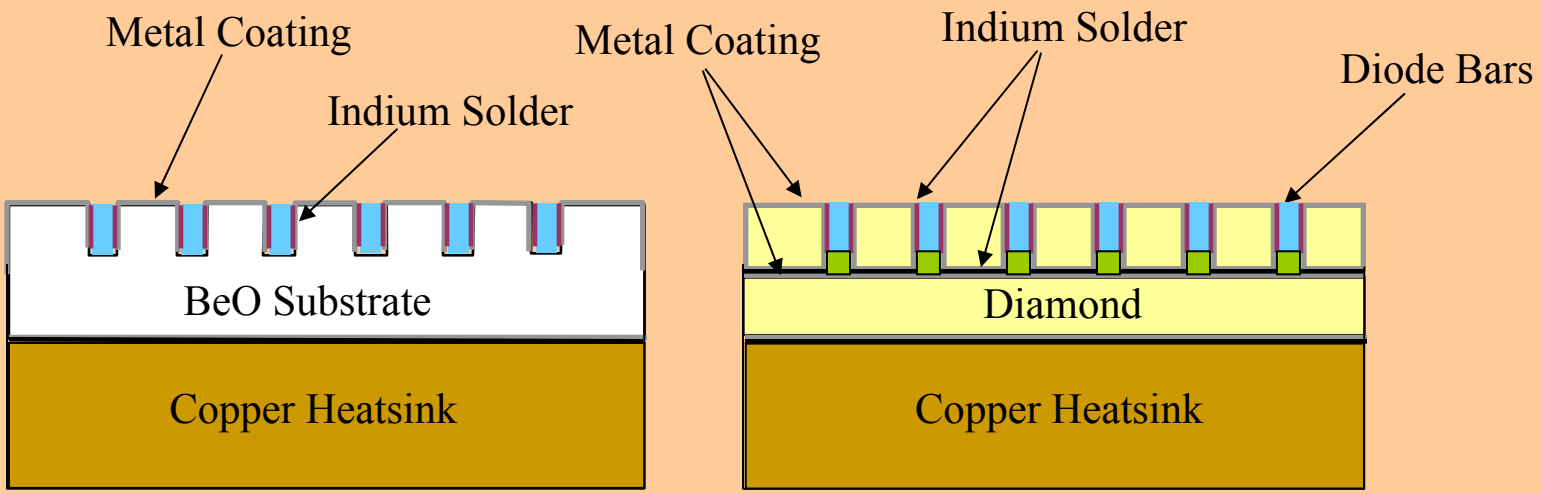


Pulsewidth	1.0 msec
Rep Rate	10 Hz
Op Temp	15°C

Advancing Laser Diode Array Technology

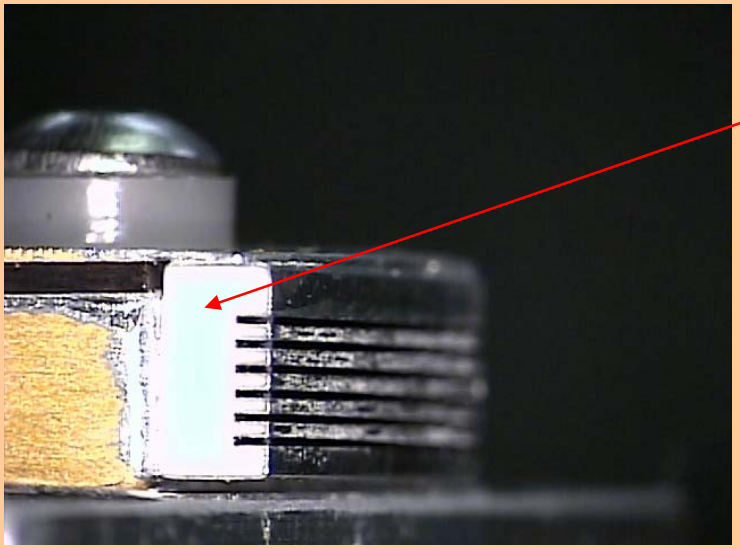
Langley Research Center (LaRC)

Fabricated several experimental Laser Diode Arrays using diamond substrate and heatsink for improved thermal characteristics and lifetime

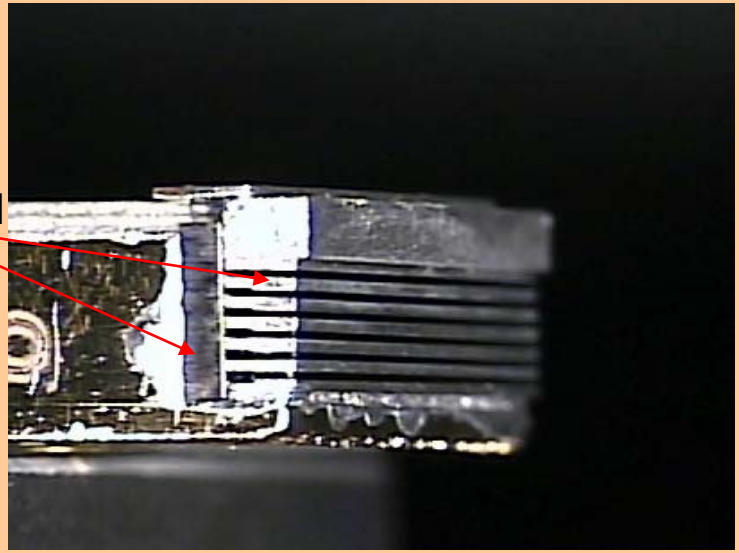


Advancing Laser Diode Array Technology

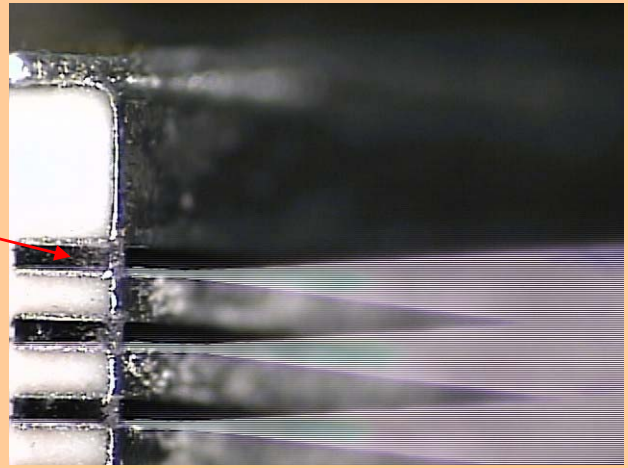
Langley Research Center (LaRC)



Standard A-Package
Coherent A-6



Diamond Package
Fabricated by CEO



792 nm Diamond Package LDA

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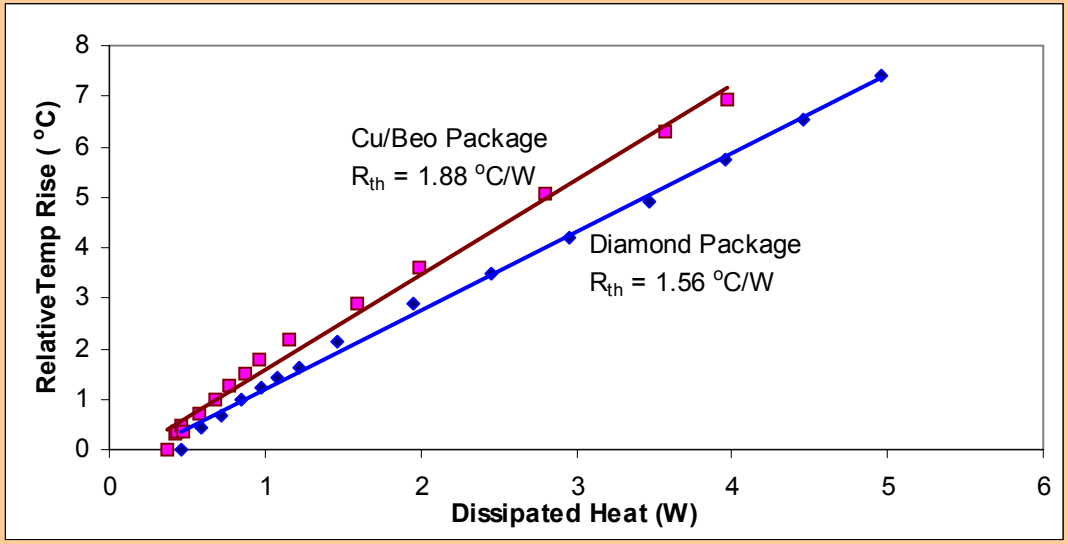
Diamond Package dissipates excess heat more efficiently than standard BeO/Cu package resulting in increased lifetime.

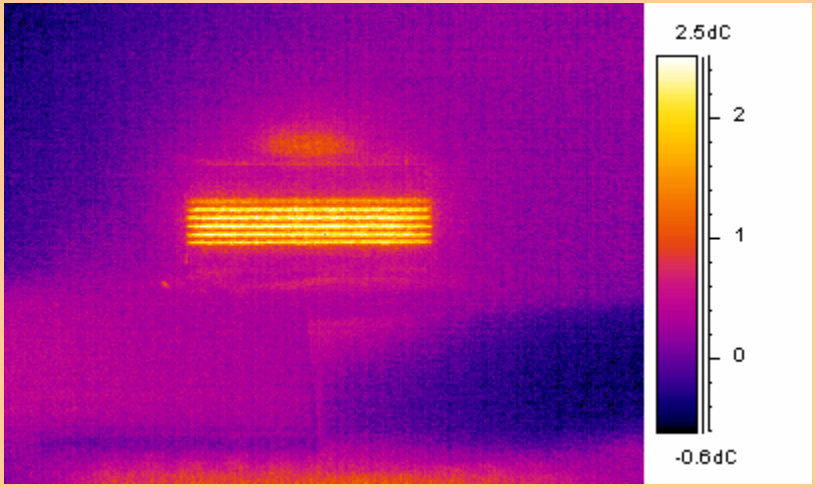
Thermal resistance of diamond package is 17% lower than BeO/Cu package



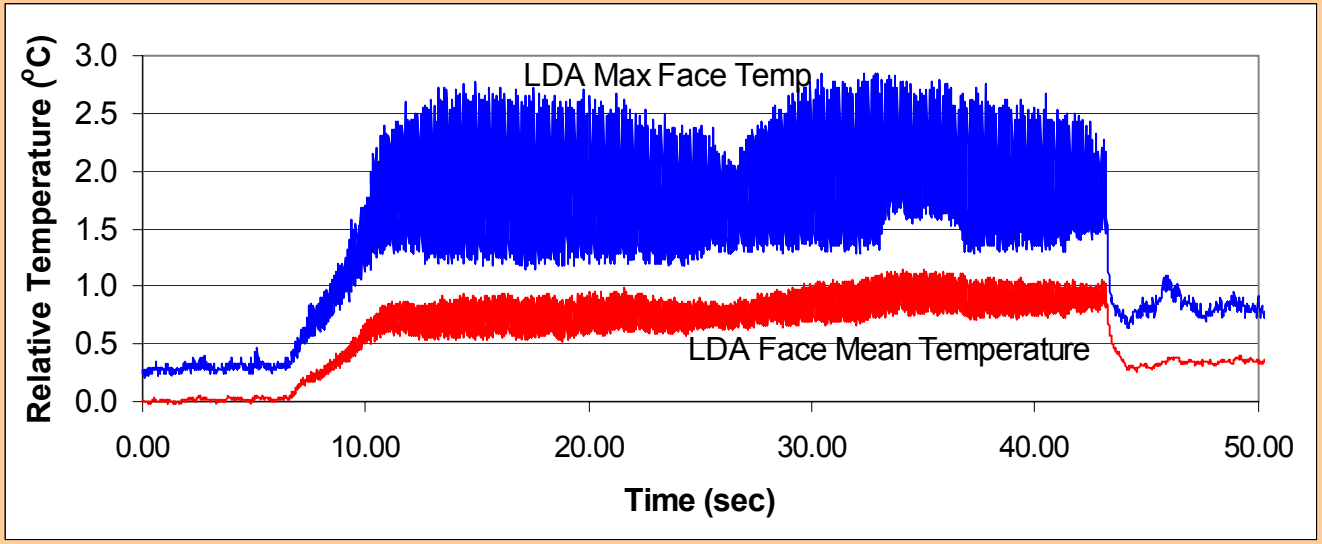
Pulsewidth	0.1 – 1.0 msec
Current	80 A
Rep Rate	10 Hz
Op Temp	15°C

Thermal Image of Diamond LDA

Langley Research Center (LaRC)

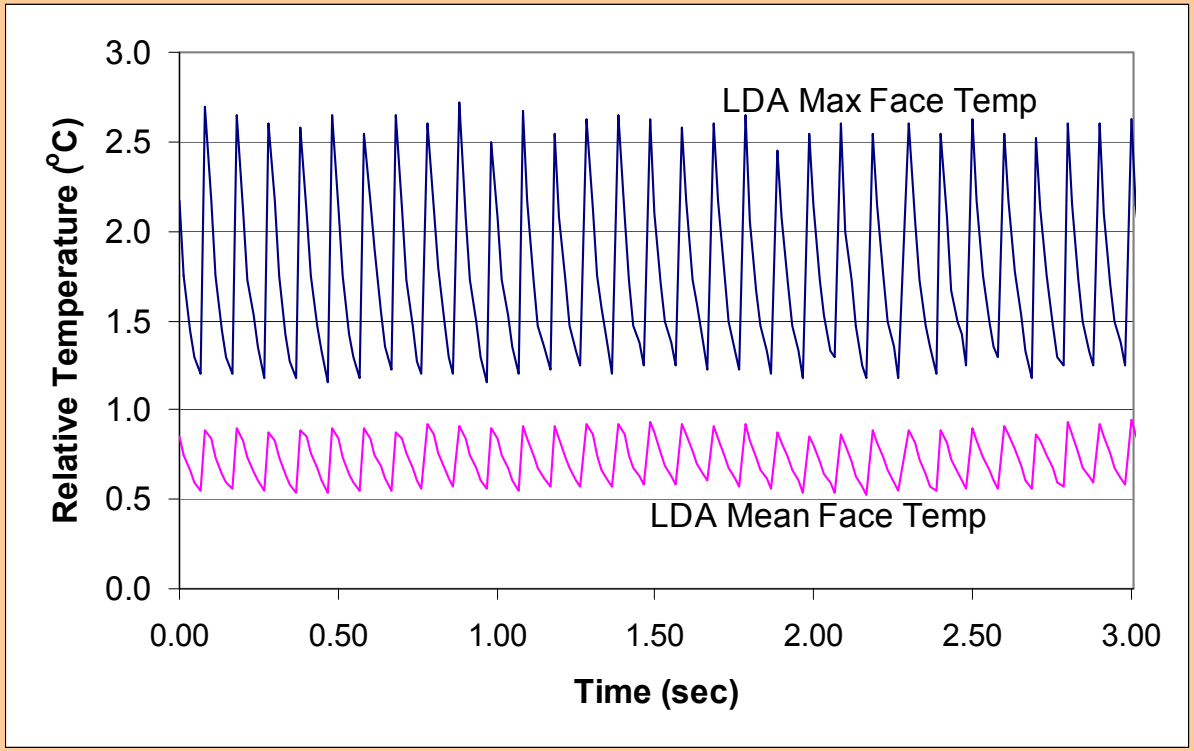


Pulsewidth	1.0 msec
Current	80 A
Rep Rate	10 Hz
Op Temp	15°C



Thermal Characteristics of Diamond LDA

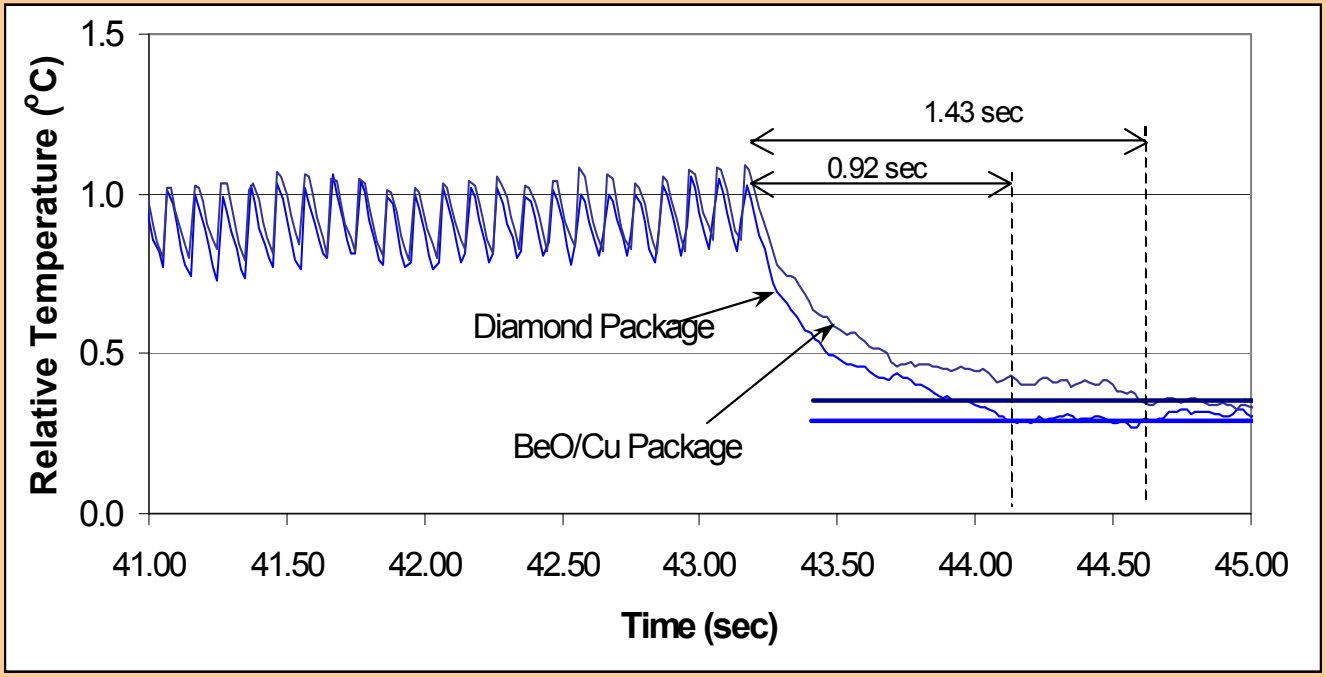
Langley Research Center (LaRC)



Thermal Cycling with applied pulsed current at 10 Hz

Thermal Characteristics of Diamond LDA

Langley Research Center (LaRC)



Diamond Package cools 36% faster

Advancement of High Power Laser Diodes for Pumping 2-micron Solid State Lasers

Langley Research Center (LaRC)

NEAR TERM PLAN

- Complete Automated Lifetime Test Station
- Complete characterization of diamond LDA packages
- Continue investigation of standard LDA Packages (A and G)
- Developed new advanced LDA packages
- Investigate operational and environmental effects on LDAs lifetime and reliability

Laser Diode Characterization/Lifetime Test Facility

Langley Research Center (LaRC)

STATUS

- Completed Characterization Test Station
- Began performance characterization of laser diode arrays
- Development of the Lifetime Test Station will be soon completed